SURFING THE CITY: *Towards context-aware mobile exploration*

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Abstract. This paper describes the rationale for a navigational system that supports context-based exploration of the urban environment. While many navigational tools support wayfinding, they are based on targeted search, requiring the user to have a predetermined destination. Existing applications do not offer navigational mechanisms that base their recommendations on the user's unique context information. Customised recommendations present the user with relevant routes they may not have discovered on their own. In this paper, a parallel is drawn between wayfinding in the physical world and the virtual, with web surfing acting as a metaphor for a particular style of interaction with the physical environment. Similarly, the framework for this system presents suggested routes to the user according to their unique contextual setting, which is anticipated to allow a more explorative engagement with their physical environment.

Keywords. Mobile computing; context-awareness; urban interaction.

1. Ubiquitous Computing Informing Environmental Negotiations

The Internet has made possible several novel forms of communication, revolutionising it in the way carrier pigeon, Morse code and telephone lines did in their time. Through the availability of, and access to, virtual information while on the move, the user is now, more than ever, connected in real-time to the rest of the world. The extent to which this 'always-online' status affects their activities is still to be discovered.

The pervasiveness of ubiquitous computing means mobile devices are being used in many different situations and locations, requiring new and different methods of interaction. The way users engage with their surrounds is an important field of research for: (i) those invested in the design of public spaces (urban designers and planners), (ii) the stakeholders (such as the businesses and marketers who advertise in public spaces) and (iii) the individual who wants to get more out of interactions with their surrounds. With the prolific establishment of mobile network infrastructure and locative technology in cities, and the ubiquity of mobile computing devices, the physical world is more tightly intersecting with the virtual, causing the boundaries between the two to increasingly blur.

1.1. DEFINING THE ENVIRONMENT

Throughout history, cities have sprung up in locations where there has been a need for centralised services, such as around a key water source, marketplace, industrial area, or at the intersection of trade routes. They served as centres of communication for the surrounding locals and provided a rich hub for the growth of culture: the arts, scientific research and technical innovation. Ubiquitous, mobile computing and infrastructure is changing how we use and define cities. Through these technologies, our primary resource, information, is more easily accessed and more widely available, shifting the focus off the geographically located information that cities traditionally provide, to a spatially distributed model. Despite this trend towards distribution, cities will still serve the function of connecting people, but this will increasingly happen through technological connectivity, which will redefine the way in which people use cities.

Doheny-Farina (1996, p123, 127) writes that by connecting everyone, a sense of place is abstracted, and by virtualising human relations we increase our (physical) isolation. To overcome this, he advises the user to steer their participation in the net toward ways that better integrate them and others into their local geophysical communities. Mobile computing provides the means to do this by coupling virtually accessible information with physically sensed information. In doing so, technologies are used to serve, and not to transcend localities. Mitchell (1995) proposes that cities existing as geophysical places integrating the virtual can thrive if freedom of access and freedom of expression is permitted, and that the physical locations are designed to attract and be attractive to users. This suggests a symbiotic relationship between city-space and cyberspace based on ensuring the technology is a social class leveller (and not monopolised), and that the spaces in which interactions take place reflect the needs of the users. Designing urban spaces that fulfil the users' needs requires knowledge about their activities and interactions within and between these city spaces.

The way we think about and use spaces is changing, as emphasis is taken away from the customisation of spaces to suit specific tasks (Mitchell, 1999; 2003) and placed on broadening the kinds of activities that take place there. This new, third wave of computing (Weiser, 1999) is not only changing the kinds of activities we undertake but also the nature of existing activities. As old boundaries converge and collapse and as activities change, so too will the public spaces which they occupy (Soja, 2003; Mitchell, 1995). This will in turn lead to new ways of interacting with public spaces.

1.2. INTERACTING WITH THE ENVIRONMENT

Digital information storage and retrieval systems such as relational databases and the World Wide Web are designed to support wayfinding through indexing, hyperlinks and efficient search mechanisms. In contrast to directed search, web surfing is a method for users to traverse the net from link to link with no end goal: no real search criteria. The enjoyment of such non-directed "search" arises from the journey itself and from the discovery of unexpected information along the route.

In the physical context of cities, the Fl neur, a product of the French Bourgeoisie (Baudelaire, 1964), wanders the city, changing course whenever something of interest catches his attention. He is aware of the rules and culture of the city and uses intuition, not a compass or street directory, to navigate (Benjamin, 1983; de Certeau, 1984). His receptiveness to diversion allows unexpected aspects of the city to be revealed through chance interactions and unforeseen communications.

In a similar style to the Fl neur, a web surfer hopes to gain novel experiences by following links that arouse his curiosity. Thus freed from the demands of targeted search, his navigation and reading of the material is not directed or tainted by expectations. Rather than judging information by preconceived criteria, he finds joy in assessing the material for its own merit. Similarities between the Fl neur and Web Surfer have been explored in Luke (2005).

Table 1 outlines six distinct styles of interacting with the urban environment. They are listed from the most passive, with the observer merely watching as scenes unfold, to the most aggressive–the Traceur, viewing boundaries as obstacles to physically overcome. For further insight, the table can be restructured according to mental engagement with the surrounds. Under this classification, the Fl neur user ranks above Tourist and Geocacher due to their highly inquisitive and analytical minds.

TABLE 1. Passive to active ways of interacting with the urban environment.

User	Style	Level of Interaction	Level of Engagement
Observer	From a static location (office window, park bench) casually watches life unravel with the city as the backdrop.	Static	High
Teleporter	Rushes to destination via shortest route, not interested in experiencing the environs. May be interested in relevant waypoints.	Minimal	Minimal
Flâneur	Leisurely exploration of the city lacking defined destination.	Moderate	Very high
Tourist	Interested in viewing landmarks & visiting a diverse range of locations that typify the city.	Moderate	High
Geocacher	Utilises locative technology to treasure hunt.	High	Moderate
Traceur	Views structures as a physical challenge in navigating the city.	Very high	Moderate

1.2. REDEFINING THE ENVIRONMENT

In 1978 the literary philosopher, Wolfgang Iser wrote:

> "The literary work has two poles, which we might call the artistic and the aesthetic; the artistic refers to the text created by the author and the aesthetic to the aesthetic realisation accomplished by the reader."

Similarly, the designer imposes an artistic vision on an environment and the user, in traversing the environment, creates their own aesthetic realisation, which is often not in accordance with the designers' original intent. In some situations, this conflict impacts directly upon the environment, such as with the case of Desire Lines (Frick, 1987; Myhill, 2004), which show a discrepancy between the routes intended for pedestrians by designers and those actually taken by them. *Desire Line* is the term given to a path etched through fields by heavy pedestrian traffic. They traditionally occur in places where the intended path travels a circuitous route and a shortcut is taken across grassy spaces. Over time and repeated wear, this leaves a visible mark on the environment. These visual representations of 'desired paths' have often caused urban planners to rethink their designs to accommodate this emergent behaviour. This, naturally, results in the redefinition of spaces.

Desire Lines do not always leave a visible effect on the environment. They encompass any situation where evidence is left of the user's desired purpose (Myhill, 2004). This extends to virtual desire lines such as website statistics uncovering trends in usage patterns, people flow caught on camera and brake marks on roads occurring at points where drivers spot speed cameras. The invisible paths taken by users through urban environments are also a type of desire line that can be made visible with GPS tracking technology. Visualisation techniques can highlight potential problem areas such as heavy traffic flow and instances where irregular routes are taken.

A handheld location-sensitive device can render the invisible, visible. Where previous evidence (such as the desire line in its traditional sense) was hard etched into the physical environment, custom paths can now be electronically recorded, opening the way for more detailed and accurate representations of user-environment interaction. This paper proposes that contextual information, such as the user's destination, path history and profile add some meaning to this data by revealing aspects of the users' intentions, thus augmenting the digital traces with additional meta-information and limiting the amount of open speculation required to determine the rationale behind such behaviours.

Urban planners and designers redefine the city on a structural level by accommodating user interactions. Our interactions with the environment redefine the city on a personal level by influencing how we are exposed to it and communicate with others.

2. Context adding meaning to Data

Providing contextualised information to individuals is widely recognised as an important aspect of communication (Dey, 2001; Dey and Abowd, 2000) and treads a fine line between the malicious: influencing the individual through targeted persuasive techniques, and the well intentioned: to filter information to individual requirements (Fogg 2007). However, if individuals are to make sense of their complex surrounds, contextualised information can be a useful tool to facilitate engagement with the environment by limiting the amount of information available to only that deemed to pertain to the individual user. This holds the potential to alter the way individuals act and react in their environments. The customisation of information and in particular, the assignment of contexts to individuals, provides the opportunity for people to re-associate themselves with the urban landscape as well as with other people. A tool that enables 'browsing' of the environment, by its very nature encourages a form of mental engagement that opens our awareness to new experiences. Lastly, the invisible trails we leave *en masse* through physical spaces weave together to form trends and patterns that, when recorded in conjunction with tagged context data, can be used to inform urban design, ultimately leading to environments that better reflect our needs.

To develop systems with knowledge of user situational context, it is necessary to define precisely how context is to be interpreted. This is no easy task as context is a combination of an individual's present position in space and time and his social, economic, political, historical, psychological and artistic identity, worldview, short and long-term motivations, goals and all the influences on him until that point in time (Dey and Abowd 2000). As Heraclitus observed in circa 500 BCE, no man ever steps in the same river twice, for it is not the same river and he is not the same man. Our world or environment, in this case the city, is in a constant state of flux as too, are we.

Context awareness is crucial in helping make sense of user intent and is associated with the way phenomena are experienced. Context provides the frame through which to interpret a set of data. Context can never be perfectly represented, but an approximation of the context of an instance can be achieved when that instance is placed in relation to other instances within the collected data set and within the known limitations of that dataset. It is therefore the distance between instances (their lack of dissimilarity rather than their similarity) that can be used to inform or to reveal trends.

In this research, Schmidt's *et al.* (1999) definition of context is adopted, simply stated as: knowledge about the user's and IT device's state, including surroundings, situation and location.

3. The Framework

The framework for the recommender system is built on the context classification proposed by Schmidt *et al.* (1999) to support a personalised, urban exploration system. Although others (Biegel and Cahill, 2004; Gellersen *et al.*, 2002; Sousa and Garlan, 2002) have proposed frameworks for context aware computing, their focus has been on the development of systems that can detect and interpret contextual aspects of an environment, emphasising the software engineering aspects of programming sensors to specify contexts or developing rules and architectures to hierarchically sort and classify contexts. Other research (Espinoza *et al.*, 2000; Hightower *et al.*, 2005) has focused on location as the sole input of context, but does not provide the necessary mechanisms to support multiple contextual inputs, which is required for this research.

The framework developed from this research supports: (i) a variety of input types (in addition to location), (ii) a mechanism for sorting input data into contexts, (iii) context information as a filter in a navigational situation and (iv) feedback to allow the adjustment of context groupings.

Components of the framework, Figure 1, consist of the user and their mobile device (the client), located in the physical environment and the server, located remotely. The user and their environment contribute a range of context data to the server via the client, including user-profiling data and GPS coordinates.

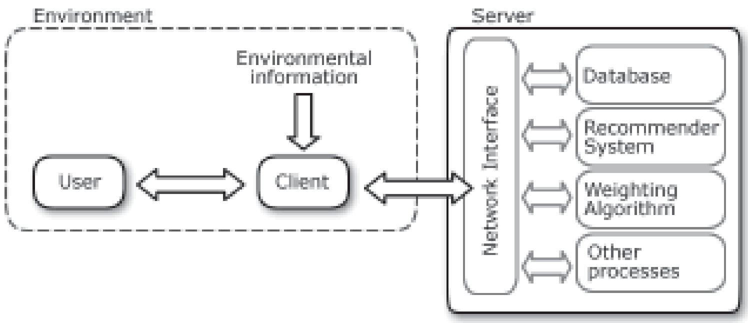

Figure 1. Information flow between elements of the framework (Paulini and Schnabel, 2007).

The data, Figure 2, is sorted into contexts by the recommender system, which is responsible for identifying possible routes based on a (dis)similarity measure. Context information is sent to the client as a recommended route point and feedback about whether the user acted on the suggestion is obtained via a locational update which adjusts future recommendations.

The framework is described detail in Paulini and Schnabel (2007).

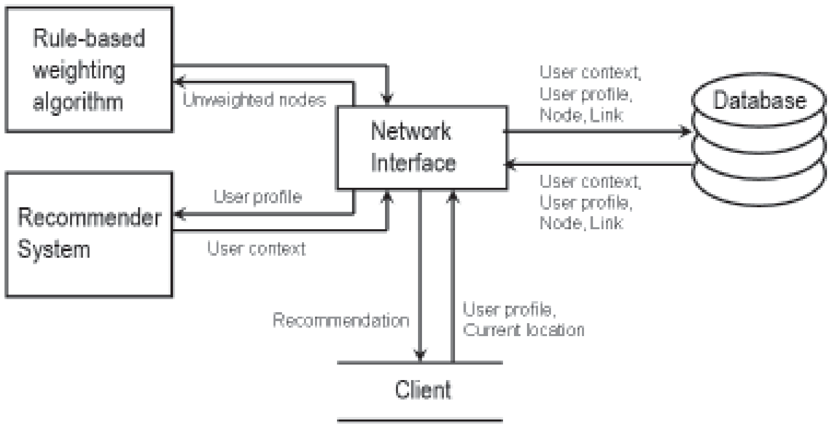

Figure 2. Information flow around the network interface (Paulini and Schnabel, 2007).

4. Conclusions and Discussion

At this locus of intersection between the physical and virtual worlds, mobile computing acts as a mediator and the portal through which the two are accessed, and engages with a third world–that of the user's inner or mental state. Mobile computing is able to bridge the gap between virtuality and reality because the physical world requires computing that can transcend location, and the virtual provides the means to support non-geo-specific access. The way the physical and virtual are brought together shapes the way environmental stimuli are experienced. Mitchell (2005, p6) says it best, when he describes the visual narrative of the physical journey:

> Like music that gains its effect from both the simultaneity of sounds and the unfolding succession of sounds, then, the interconnected spaces of a city construct a mise-en-sc ne through both the synchronic effect of simultaneously visible elements and relationships and the diachronic effect of elements and relationships presenting themselves sequentially to moving observers.

Building on this metaphor, the addition of information from the virtual realm to physical space (that of the mobile device itself) can be seen as simply adding another instrument to the score, enhancing (or at any rate, altering) the composition.

The key elements to supporting interpretation of the environs are the filtering of information to represent and suggest, and the manner in which the information is depicted. The first can be said to customise, the second to communicate. Customisation involves selecting information from a pool of data based on an awareness of the user's current context. Communication requires an intuitive interface, discussed in Paulini and Schnabel (2007).

For designers of the urban environment, understanding emergent behaviour, the configurations of people in spaces and the way those spaces are defined by the patterns people create within them is crucial in forming or disputing theories on, among other things, Architectural determinism, but also to inform design practice. In tagging paths with users' unique contexts, the system provides meta-information that can be data-mined to reveal the emerging needs of the city's users. The information collected by the system can be modelled with parametric design tools, which allows designers to accommodate unpredictable events without diverging from the overall urban framework and to create urban spaces that reflect varied human activities without specifying particular functions (Schnabel, 2007). The information revealed by such a system can be used to speculate about user motivation and interests, providing a much richer foundation on which to test theories than if paths alone were provided. The information also lends itself to a more democratic and open-style of planning, and supports the use of new design methods that address these emerging needs rather than doggedly adhering to a fixed master plan.

This paper has described the conceptual basis for a context-based system for mobile exploration of urban environments. An analogy has been drawn between the structure of the web and that of the physical environment, with the virtual activity of web surfing likened to the physical activity of Fl nerie. This comparison provides the necessary conceptual link to establish mobile computing as a platform that enables users to browse their physical environment rather than use it solely for targeted search. The need for context-awareness in mobile computing has been recognised and the broad nature of context (Schmidt *et al*., 1999) has been addressed by incorporating both human as well as environmental factors into the system. Conjectures concerning the impact such a system may have on a user's engagement with their environment have been discussed.

5. Future Work

The prototype created in the course of this research (Paulini and Schnabel, 2007) demonstrates, on simulated data, that contextual information affects the recommendation of route points. The system requires testing and evaluation in an urban setting with a series of user studies to reveal its validity as a tool for altering user paths based on personal context data and its effectiveness in engaging the user with their surrounds.

Further research can be conducted to identify different user types within the context of this framework. This involves understanding and modelling various forms of interaction with the urban environment and perhaps more importantly, developing a wider understanding of context that encompasses other groups such as the elderly and handicapped; real concerns in our aging population, and for whom such a system would immensely benefit their interactions with the urban environment and affect their quality of life.

The outcomes of this research may lead to developments in four specific areas: (i) user interaction and perception of the urban environment, (ii) uses of ubiquitous computing, (iii) exploration of context-awareness in mobile computing and (iv) the furthering of our understanding of the social implications of such technologies, both in the way urban design and planning is conducted and in the ethics associated with the uses of this technology. A system that tracks users' paths and tags them with their personal, contextual information has enormous appeal in the area of urban planning, however, there may be ethical implications involved with managing, storing and accessing personal information which requires further investigation.

References

Baudelaire, C: 1964, The Painter of Life and other Essays; As translated and edited by J Maine, 1986, Da Capo Press, New York.

Benjamin, W: 1983, Charles Baudelaire: A lyric poet in the era of high capitalism / Walter Benjamin; Translated from the German by Harry Zohn, Verso, London.

Biegel, G and Cahill, V: 2004, A framework for developing mobile, context-aware applications, in *Proceedings of the 2nd IEEE International Conference on Pervasive Computing and Communications,* IEEE Computer Society, Washington, DC, pp. 361-365.

De Certeau, M: 1984, The Practice of Everyday Life, Berkeley, University of California Press, pp. 91-110.

Dey, AK: 2001, Understanding context, Personal and Ubiquitous Computing **5**(1): 1617-4917.

Dey AK and Abowd, GD: 2000, Towards a better understanding of context and context-awareness, Conference on Computer-Human Interaction, Workshop on the What, Who, Where, When, Why and How of Context-Awareness, The Netherlands.

Doheny-Farina, S: 1996, The Wired Neighborhood, New Haven, Yale University Press, pp. 123-127.

Espinoza, F, Persson, P, Sandin, A, Nystr m, H, Cacciatore, E and Bylund, M: 2001, GeoNotes: Social and navigational aspects of location-based information systems, in GD Abowd, B Brumitt and SAN Shafer (eds), *Ubicomp 2001,* Springer-Verlag, Berlin Heidelberg, pp 2-17.

Fogg, BJ: 2007, The future of persuasion is mobile, *in* BJ Fogg and D Eckles (eds), *Mobile Persuasion: 20 Perspectives on the Future of Behaviour Change,* pp. 5-11.

Frick, T: 1987, Rebuilding Central Park, *Technology Review.*

Gellersen, HW, Schmidt, A and Beigl, M: 2002, Multi-sensor context-awareness in mobile devices and smart artifacts, Mobile Networks and Applications **7**: 341-351.

Hightower, J, Consolvo, S, LaMarca, A, Smith, I and Hughes, J: 2005, Learning and recognizing the places we go, in M Beigl et al. (eds), *UbiComp 2005,* LNCS 3660, Springer-Verlag, Berling Heidelberg, pp. 159-176.

Iser, W: 1978, The Act of Reading: A Theory of Aesthetic Response, The John Hopkins University Press, Baltimore, Maryland.

Luke, R: 2005, The Phoneur: Mobile commerce and the digital pedagogies of the wireless web, *in* P. Trifonas (ed), *Communities of Difference: Culture, Language, Technology*, Palgrave MacMillan.

Mitchell, WJ: 1995, City of Bits: Space, Place and the Infobahn, MIT Press, Cambridge, MA.

Mitchell, WJ: 1999, e-topia Urban life, Jim–but not as we know it, MIT Press, Cambridge, MA.

Mitchell, WJ: 2003, Me++: The Cyborg Self and the Networked City, MIT Press, Cambridge, MA.

Myhill, C: 2004, Commercial success by looking for desire lines, in M. Masoodian, S. Jones and B. Rogers (eds), 6th Asia Pacific Computer-Human Interaction Conference (APCHI 2004), Rotorua, New Zealand, Springer-Verlag.

Paulini, M and Schnabel, MA: 2007 Surfing the city: An architecture for context-aware urban exploration, Proceedings of the 5th International Conference on Advances in Mobile Computing and Multimedia, Jakarta, Indonesia, December 3-5, pp. 31-40.

Schilit, BN, Adams, NI, Want R: 1994, Context-aware computing applications, in Proceedings of the IEEE Workshop on Mobile Computing Systems and Applications, Santa Cruz, CA.

Schmidt, A, Aidoo, KA, Takaluoma, A, Tuomela, U, Van Laerhoven, K and Van de Velde, W: 1999, Advanced interaction in context, in *Proceedings of the 1st international symposium on Handheld and Ubiquitous Computing, Springer-Verlag,* London, UK, pp. 89-101.

Schnabel, MA: 2007, Interplay of Parametric Design Methods, in Integrating Technologies for Computer-Aided Design, Sydney, Australia, Springer Academic Press, pp. 237-250

Soja, E: 2003, Writing the city spatially, City: analysis of urban trends, culture, theory, policy, action 7(3):269-281.

Sousa, JP and Garlan, D: 2002, Aura: An architectural framework for user mobility in ubiquitous computing environments, in J. Bosch, M. Gentleman, C. Hofmeister and J. Kuusela (eds), *Software Architectures: System Design, Development, and Maintenance* (3rd IEEE Conference on Software Architecture), Kluwer, Montreal, pp. 29-43.

Weiser, M: 1999, The computer for the 21st century, ACM SIGMOBILE Mobile Computing and Communications Review **3**(3): 3-11.